TENNESSEE DEPARTMENT OF ENVIRONMENT & CONSERVATION DIVISION OF WATER SUPPLY

TDEC
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

Out of Sight
Is Not
Out of Mind

GROUND WATER MANAGEMENT SECTION

TENNESSEE
Ground Water
305b Water Quality Report
November 2002

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Introduction

This report has been prepared by the Ground Water Management Section of the Division of Water Supply. The intent of this report is to provide the public with an overall characterization of ground water quality and hydrogeology for Tennessee. The federal Clean Water Act of 1987 requires each state to assess water quality and report results to the public. These assessment documents, known as the 305(b) Report (named after the section of the act that requires them), are the official mechanism for states to document efforts to fulfill the federal Clean Water Act requirements. This Ground Water 305(b) Report has been prepared by the Division of Water Supply to fulfill this requirement.

This report addresses ground water quality issues for Tennessee which are excluded from the 305(b) "Status of Water Quality in Tennessee Year 2002 305(b) Report" prepared by the Division of Water Pollution Control.

Ground Water Quality and Aquifer Vulnerability in Tennessee

Tennessee has been blessed with an abundance of high quality ground water. Once thought to be safe from contamination, there is increasing awareness that ground water needs to be protected as a valuable resource. It can be quite vulnerable to contamination, particularly in karst terrain or in unconfined sand aquifers. This vulnerability is particularly true for contamination from the highly mobile and widely used volatile organics (chlorinated solvents and gasoline components). Aquifer vulnerability is a complex set of issues, not the least of which is the varying geology and hydrogeologic conditions across Tennessee (Table 1 and Figure 1). The two major aquifer types in Tennessee are the sand aquifers of West Tennessee and the karst limestones (carbonates shown in Figure 1) of Middle and East Tennessee.

Table 1
TENNESSEE'S HYDROGEOLOGICAL CHARACTERISTICS

WESTERN TENNESSEE

Alluvial Aquifer. The Alluvial Aquifer in western Tennessee underlies the flood plain of the Mississippi River and its tributaries and the southern end of the Western Valley of the Tennessee River. This aquifer, which consists of sand and gravel with interbeds of clay, is used primarily for rural domestic supplies and for some irrigation. This aquifer is capable of yielding more than 1,500 gallons per minute to wells in the Mississippi River area. In some areas iron concentrations which exceed 1.0 milligram per liter are a problem.

Memphis Sand. In western Tennessee, the Memphis Sand ("500 Foot Sand") is the primary aquifer of use. The Memphis Sand underlies approximately 7,400 mi^2 in western Tennessee. It primarily consists of a thick body of sand that contains subordinate lenses or beds of clay or silt at various horizons. The sand ranges from very fine to very coarse, but commonly it is locally fine, fine to medium, or medium to coarse. The Memphis Sand ranges from 0 to about 900 feet in thickness but, where the original thickness is preserved, it is about 400 to 900 feet thick. The base of the Memphis Sand dips westward at rates of about 20 to 50 ft/mi, but it is faulted at many places. The Memphis Sand yields water to wells in most of the area of occurrence and, where saturated, makes up the Memphis aquifer.

Recharge to the Memphis aquifer is from precipitation on the outcrop, which is a broad belt across western Tennessee, or by downward infiltration of water from the overlying fluvial deposits and alluvium. In the outcrop-recharge belt, the Memphis aquifer is under water-table conditions (unconfined), and the configuration of the potentiometric surface is complex and generally conforms to the topography. In the subsurface to the west of the outcrop-recharge belt where the Memphis aquifer is confined (artesian), the potentiometric surface generally gently slopes westward, and water moves slowly in that direction.

Fort Pillow Sand. The Fort Pillow Sand ("1400 Foot Sand") underlies the Memphis Sand and the Flour Island Formation in the western portion of West Tennessee. The Flour Island Formation acts as an upper confining layer to the Fort Pillow and a lower confining layer for the Memphis Sand. The sand is fine to medium; thickest in the southwest portion of the Memphis area; thinnest in the northern and northeastern parts. Once the second principal aquifer supplying the city of Memphis; still used by industry. Principal aquifer providing water for municipal and industrial supplies west of the Mississippi River.

Cretaceous Sand. The Cretaceous Sand aquifer is composed of the McNairy and Coffee Sands, and the Tuscaloosa Formation. The formations crop out in the eastern part of the Coastal Plain and underlie the Tertiary Sand to the west. The Cretaceous Sand aquifer (recently renamed the Western Valley aquifer) is used primarily in and near the outcrop area where it supplies water for municipal, industrial, and rural use. Water in the aquifer is unconfined in the outcrop area and confined in the subsurface farther west. The Cretaceous Sand aquifer is underlain by the Ordovician Carbonate aquifer and the Cambrian-Ordovician Carbonate aquifer (Knox).

Table 1 (continued)

MIDDLE TENNESSEE

<u>Mississippian Carbonate (*KARST*).</u> The Mississippian Carbonate aquifer (recently renamed the Highland Rim aquifer) consists of flat-lying carbonate rocks of Mississippian age and underlies the Highland Rim physiographic province. Land in the eastern, northern, and southern parts of the province is predominantly undulating, whereas the western part is more dissected and hilly to steep. Altitude of land surface averages about 1,000 feet above sea level. The bedrock formations weather of form a deep (up to 100 feet thick) chert regolith, which stores ground water and releases it to openings in the bedrock. Fractures in the bedrock have been widened selectively by solution, permitting rapid transmission of water, as well as providing some storage. Well yields commonly range from 5 to 50 gal/min.

<u>Ordovician Carbonate (*KARST*).</u> The Ordovician Carbonate aquifer (recently renamed the Central Basin aquifer) consists of generally flat-lying carbonate rocks of Ordovician age and underlies the Central Basin physiographic province. The outer part of the Central Basin is predominantly hilly and steep; average altitude of land surface is about 750 feet above sea level. Regolith in the outer part of the Central Basin ranges form less than 2 to more than 10 feet thick. Land in the inner part of the province is predominantly rolling and undulating with an average altitude of about 600 feet above sea level. Regolith cover in the inner part of the province is thin (less than a foot) to absent. Water is stored in and moves through solution-enlarged vertical joints and horizontal bedding planes. Wells commonly yield from 5 to 20 gal/min. At depth (>1000 ft) the Central Basin is underlain by the Knox Aquifer, whose upper formations can provide substantial quantities of water.

<u>Pennsylvanian Sandstone (*PREDOMINANTLY FRACTURED ROCK AQUIFER*).</u> The Pennsylvanian Sandstone aquifer (recently renamed the Cumberland Plateau aquifer) consists of generally flat-lying sandstone, shale, and conglomerate of Pennsylvanian age and underlies the Cumberland Plateau physiographic province. Land surface in this province is gently rolling to hilly, bordered by a prominent escarpment of both sides. Altitude of the plateau surface is generally between 1,700 and 1,900 feet above sea level; the height of the escarpments averages 900 feet. Regolith is generally less than 4 feet thick. Water is stored in and moves through fractures, faults, and bedding plane openings in the bedrock. Wells commonly yield from 5 to 50 gal/min.

EASTERN TENNESSEE

Cambrian-Ordovician Carbonate (*KARST*). The Cambrian-Ordovician Carbonate aquifer (recently renamed the Valley and Ridge aquifer) consists of extensively folded and faulted carbonate, sandstone, and shale of Cambrian and Ordovician age underlying the Valley and Ridge physiographic province. The rock formations crop out alternately in long, narrow belts, so that aquifer characteristics show marked areal variability. The ridges range in altitude from about 1,500 to over 7,000 feet above sea level; valleys generally range between 750 and 1,000 feet above sea level. Generally regolith is thin over the shales and sandstones and thick over the limestone. The sandstone and shale units are poor aquifers; nearly all the high producing wells and springs are in the dolomitic limestone formations, particularly the upper formations of the Knox Group (Mascot and Kingsport). The Knox aquifer is frequently singled out as a separate aquifer. Water moves through solution-enlarged fractures, which in areas may form extensive networks. The folding and faulting has produced regional anisotropy in aquifer hydraulic properties, and ground water may move preferentially in strike-parallel or strike-normal directions. Well yields commonly range from 5 to 200 gal/min.

Crystalline Rock Aquifer (*FRACTURED ROCK AQUIFER*). The Crystalline Rock aquifer (recently renamed the Blue Ridge Aquifer) consists of crystalline rock of Cambrian and Precambrian age underlying the Blue Ridge physiographic province. The province is characterized by extremely rugged terrain, with several mountain peaks higher than 6,000 feet above sea level, and valleys ranging from 1,000 to 1,500 feet above sea level. The aquifer consists of dense, fractured bedrock covered on the lower parts of the slopes with a thick mantle (as much as 100 feet) of regolith, alluvium, and colluvium. The regolith stores ground water, releasing it to fractures in the bedrock. The essentially unmodified fracture openings contribute very little to storage, functioning mainly to transmit water stored in the regolith. Wells yield from 5 to 50 gal/min.

***INFORMATION FOR THIS TABLE WAS DERIVED FROM THE FOLLOWING SOURCES:**

1. Tennessee Dept. of Health and Environment; Ground Water Management Strategy, 1988.
2. Bradley, M. W., and Hollyday, E. F., 1985. Tennessee ground-water resources, *in* National Water Summary 1984: Hydrologic Events, Selected Water Quality trends, and Ground Water Resources: U. S. Geological Survey Water Supply Paper 2275, p. 391-396.
3. U. S. Geological Survey. 1986. Potential for Leakage among Principal Aquifers in the Memphis Area, Tennessee. Water-Resources Investigation Report 85-4295.

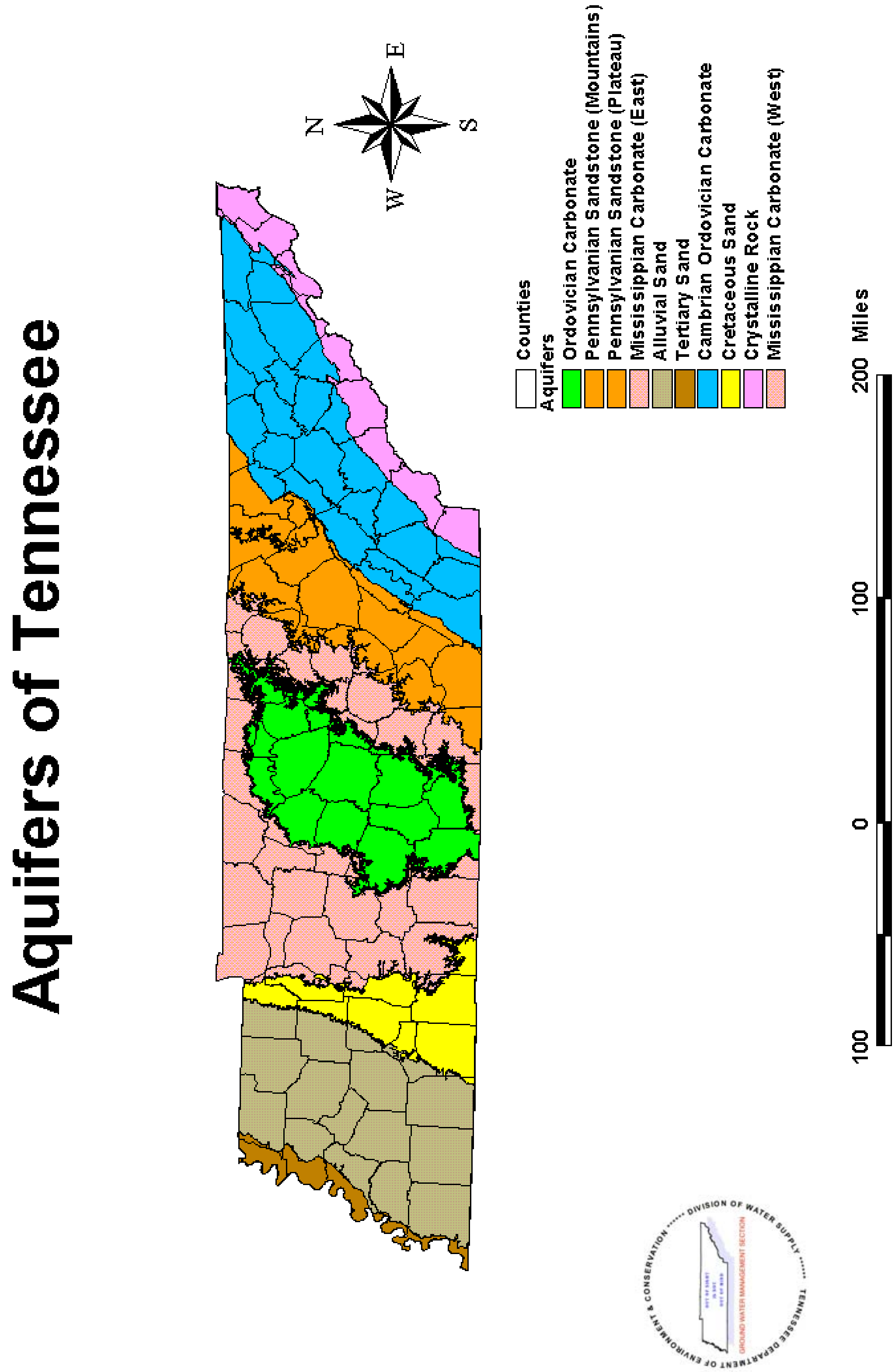

Aquifers of Tennessee
N
E
S
W
Counties
Aquifers
Ordovician Carbonate
Pennsylvanian Sandstone (Mountains)
Pennsylvanian Sandstone (Plateau)
Mississippian Carbonate (East)
Alluvial Sand
Tertiary Sand
Cambrian Ordovician Carbonate
Cretaceous Sand
Crystalline Rock
Mississippian Carbonate (West)
100
0
100
200 Miles
DIVISION OF WATER SUPPLY
TENNESSEE DEPARTMENT OF ENVIRONMENT & CONSERVATION
GROUND WATER MANAGEMENT SECTION

Figure 1

Tennessee's Sand Aquifers

West Tennessee relies almost exclusively on ground water for its water supply. The most productive aquifer in the area is the Memphis Sand (Figure 1: confined and unconfined Tertiary aquifer), supplying water to Jackson/Madison County and counties furhter to the west, including Memphis/Shelby County. There are major withdrawals at Memphis (168 million gallons per day), Jackson (>10 million gpd) and Dyersburg (>4 million gpd).

West Tennessee is particularly vulnerable to volatile organic contamination in that there is considerable industry, coupled with a high population density and the reliance on ground water. Even though Memphis/Shelby County has a confining layer (county furthest southwest on the Tennessee maps) for much of its area, it has numerous "windows" and leaks. This leaky-to-locally-absent confining layer when combined with high population density, large ground water withdrawals, and an abundance of industry and urban ground cover makes Memphis in a particularly vulnerable position as well.

Tennessee Karst Aquifers

Tennessee has an abundance of karst geology (Figure 2) which is highly susceptible to contamination. Karst areas are characterized by sinkholes, springs, disappearing streams and caves; as well as by rapid, highly directional ground water flow in discrete channels or conduits. The term karst refers to limestones and dolomites (magnesium-rich limestones) where ground water flows through solution-enlarged channels, bedding planes and microfractures within the rock. Karst systems are quite easily contaminated since the waters can travel rapidly over long distances through conduits with no chance for natural filtering processes of soil or bacterial action to diminish the contamination. Transport times across entire karst flow systems may be as short as hours or weeks, orders of magnitude faster than that in sand aquifers.

Water in karst areas is not distinctly surface water or ground water. In unconfined or poorly confined conditions, karst aquifers have very high flow and contaminant transport rates under rapid recharge conditions such as storm events. This is a particular concern for public water systems using wells or springs in karst areas. Pathogenic organisms that would not be present in true ground water can survive in ground water under the influence of surface water.

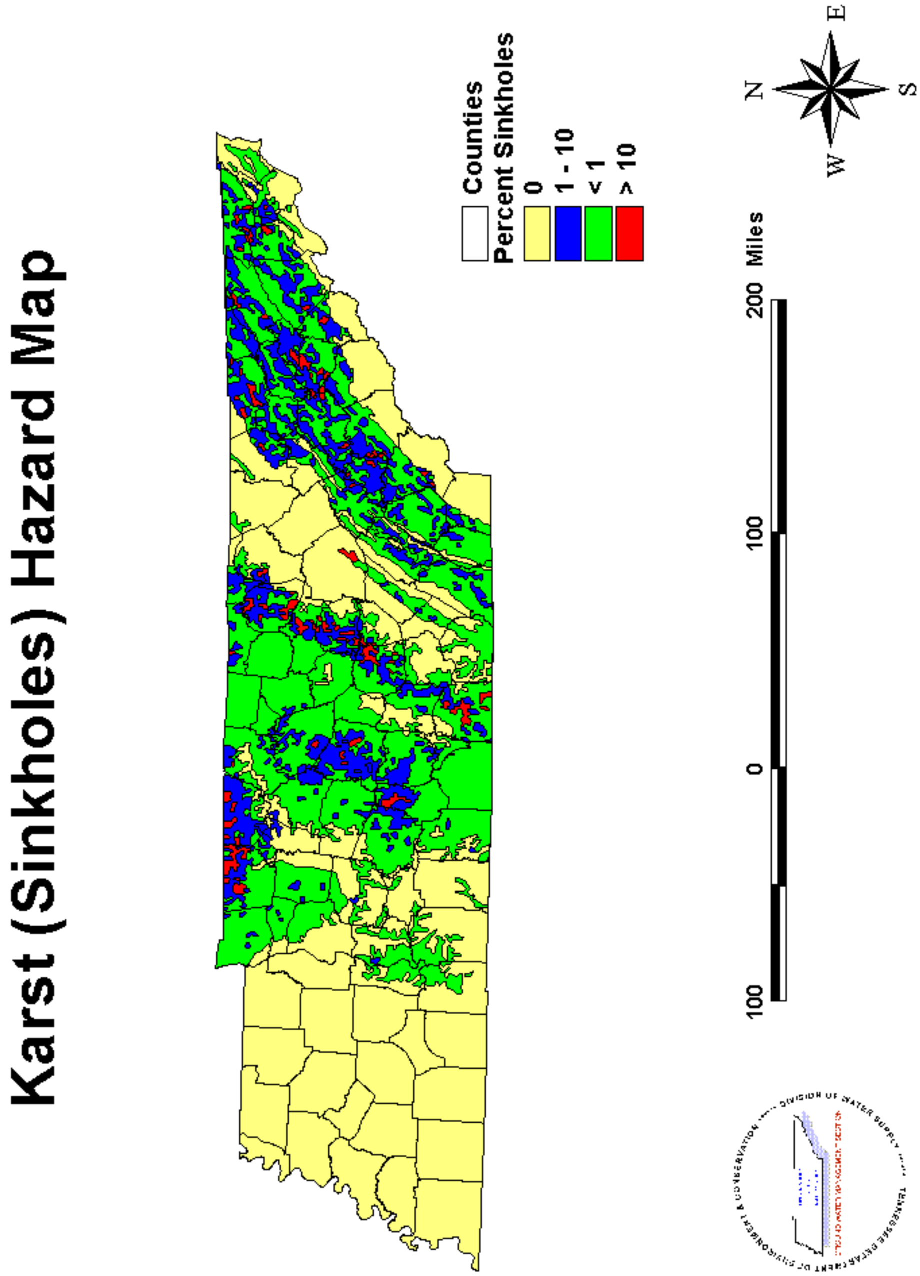
The required testing of public water systems using ground water has shown numerous instances of individual sources under the direct influence of surface water across Middle and East Tennessee. These systems are required to have their sources filtered as if they were surface water intakes or undertake a more protective management program. Approximately 2/3 of the community public water systems using ground water in Middle and East Tennessee (Figure 3) have had at least one source determined under the direct influence of surface water. There are numerous noncommunity ground water systems (churches, schools, restaurants, campgrounds, etc.) in Middle and East Tennessee which have been determined to be under the direct influence of surface water as well.

The abundance of karst in Tennessee can also be a serious construction concern in commercial, residential and industrial development due to the potential for collapse and flooding standpoint which can also lead to ground water contamination issues. A large portion of Tennessee's population reside in karst areas, including the major population centers of Nashville, Knoxville, Chattanooga, Johnson City, Murfreesboro, Cookeville and Clarksville as well as many rural communities. As Tennessee's population grows and prime land for development is used up, less desirable areas are currently being developed at higher rates than local karst systems can accommodate.

The growing awareness of both the hydrological and structural implications of karst terrain have led to considerably more involvement at the municipal level. The cities of Clarksville, Johnson City, Chattanooga, Cookeville, Knoxville, Murfreesboro and Oak Ridge have all become involved at some level with the karst issue; including the adoption of sinkhole ordinances.

There are also a large number of municipalities and other water systems that have found themselves embroiled in the karst issue with ground water sources impacted by surface water (see map), facing the construction of filtration plants or other protective measures. Approximately 2/3 of the community public water systems using ground water in Middle and East Tennessee have had at least one source determined under the direct influence of surface water (their ground water source has surface water contaminants/pathogens).

Mature (well-developed) karst areas such as Montgomery, Franklin (Mississippian Carbonates in Figure 1), Maury and Marshall Counties (Ordovician Carbonates) are particularly vulnerable to contamination. Marshall County has had several incidences of ground water contamination. These incidences include a Superfund site that has shown organic solvent contamination in springs and wells as far as 3 1/2 miles from the facility. There are known incidences of animal waste lagoons placed in sinkholes having directly impacted drinking water supplies in both Marshall and Franklin County (possibly including a public water system in Franklin County). Marshall County has even had a documented incident where adding algicide to a horse pond has impacted a neighbor's well on an adjacent property.



Karst (Sinkholes) Hazard Map
Counties
Percent Sinkholes
0
1 - 10
< 1
> 10
100
0
100
200 Miles
N
E
S
W

Figure 2

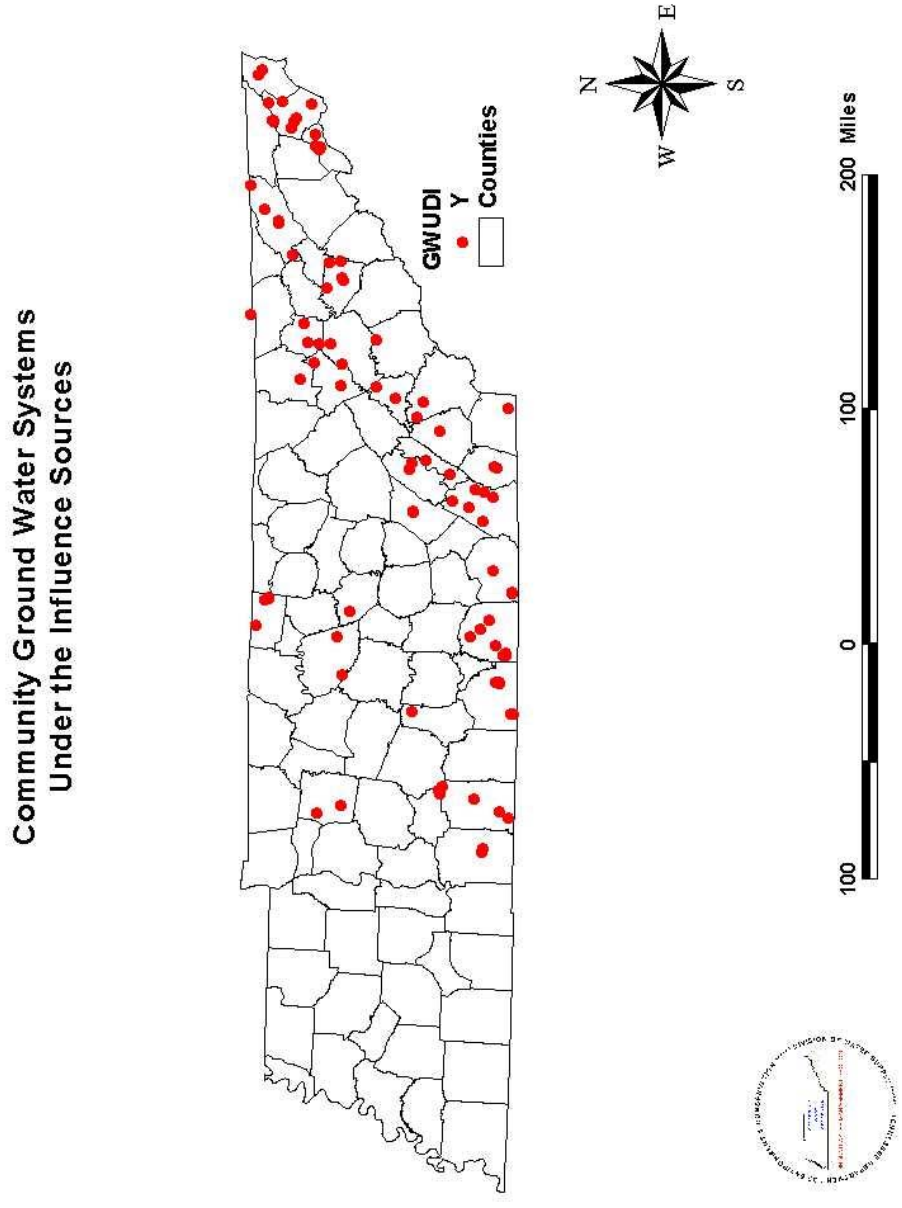

Community Ground Water Systems
Under the Influence Sources
GWUDI
Y
Counties
N
E
S
W
100
0
100
200 Miles

Figure 3

Tennessee's Public Water Supplies

More than half the population of Tennessee relies on ground water for its drinking water supplies. Community public water systems withdraw approximately 291 million gallons of per day of water, with Memphis accounting for 168 million gallons per day average production and Jackson accounting for over 10 million. There are additional withdrawals by industry and noncommunity public water supplies. Of the population relying on ground water, one in five Tennesseans relies on a private well or spring.

West Tennessee communities rely almost exclusively on ground water drawn from sand aquifers for their water supplies (Figure 4). There are many small to medium sized public water systems (up to 10,000 population) on wells and springs in East Tennessee. Most of the largest public water systems in Middle and East Tennessee (Nashville, Knoxville, Chattanooga and Kingsport) are relying on Tennessee's readily available major rivers: the Cumberland, Tennessee and Holston Rivers. Middle Tennessee as a whole relies considerably less on ground water for public water systems; however, the vulnerability still exists for private wells and springs.

The most frequently found chemicals contaminating Tennessee's public water supplies relying on ground water are chlorinated degreasers, solvents and gasoline. These are highly mobile chemicals and are widely used across the state. Several ground water sources for public water systems across the state have shown detections of chlorinated solvents, degreasers and gasoline as well as contamination at levels where additional treatment or, in most cases, abandonment of wells or springs has been required (Figure 5).

For public water systems, two areas are particularly at risk:

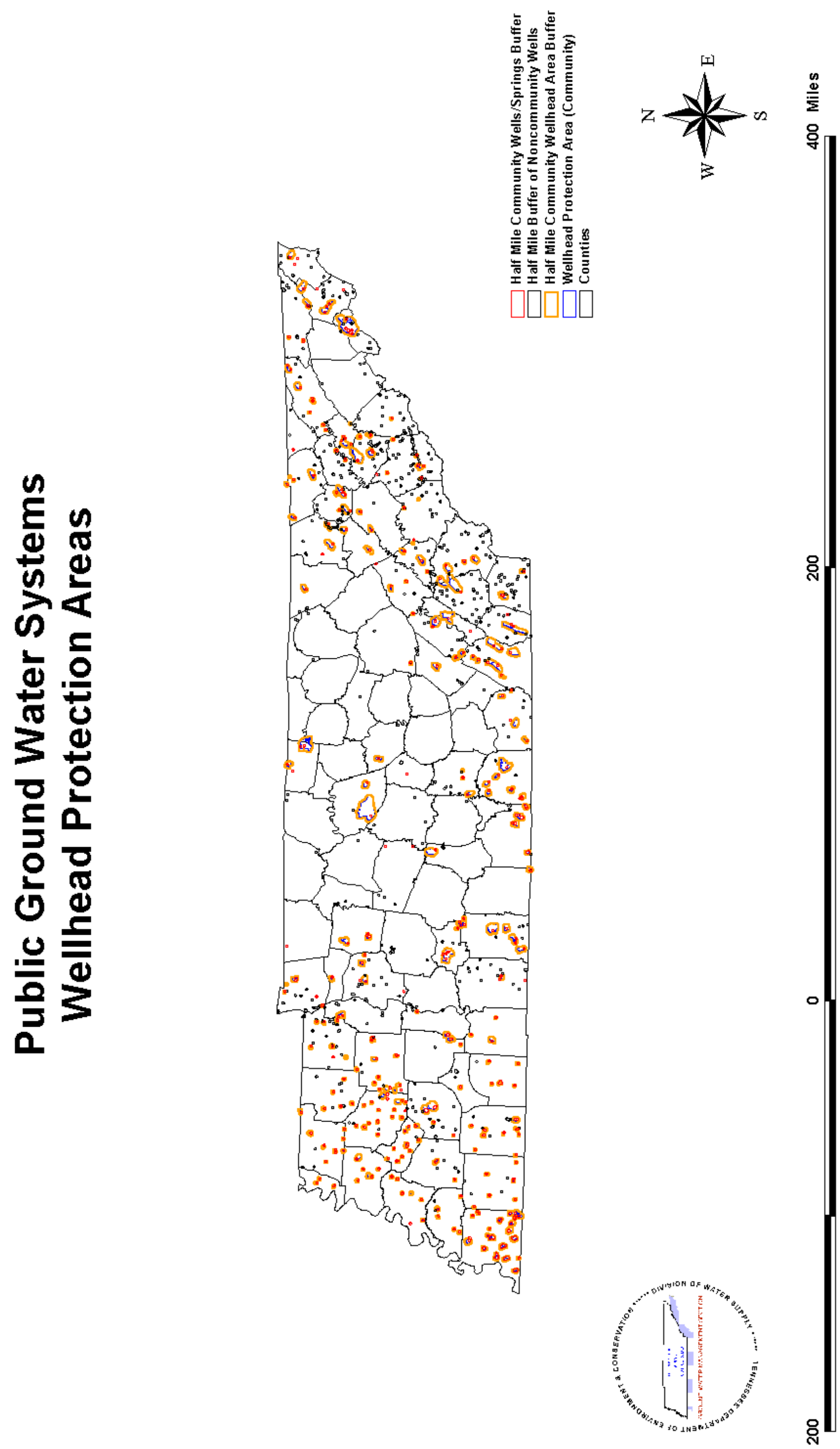
1) West Tennessee along the outcrop of the Memphis Sand (Unconfined Tertiary Sand Aquifer of Figure 1) and areas further west. The contamination which has been identified in public water systems in West Tennessee falls largely within the Memphis Sand outcrop area or within the area where a limited confining layer exists. (Figure 6).

2) Karst aquifers in the Valley and Ridge Province of East Tennessee (as well as the crystalline aquifer in the NE corner of the state). The karst aquifers of Middle Tennessee are also vulnerable; however, there are fewer public water systems relying on ground water in Middle Tennessee.

Public water systems relying on ground water in the Valley and Ridge of East Tennessee are in a particularly vulnerable karst situation (Cambrian - Ordovician Carbonates of Figure 1). The bedrock is highly faulted, fractured, and folded. The bedding planes are typically dipping at 30 to 60 degrees and can be nearly vertical, further complicating ground water flow. There are several inter-related factors in addition to the hydrogeologic factors which combine to make this area prone to contamination:

1) The area is highly industrialized with abundant potential contamination sources and known releases.

2) The area has a relatively high population dependent on ground water supplies (Figure 4).



Public Ground Water Systems
Wellhead Protection Areas
Half Mile Community Wells/Springs Buffer
Half Mile Buffer of Noncommunity Wells
Half Mile Community Wellhead Area Buffer
Wellhead Protection Area (Community)
Counties
N
E
S
W
200
0
200
400 Miles

Figure 4

Ground Water Contamination for Public Water Systems

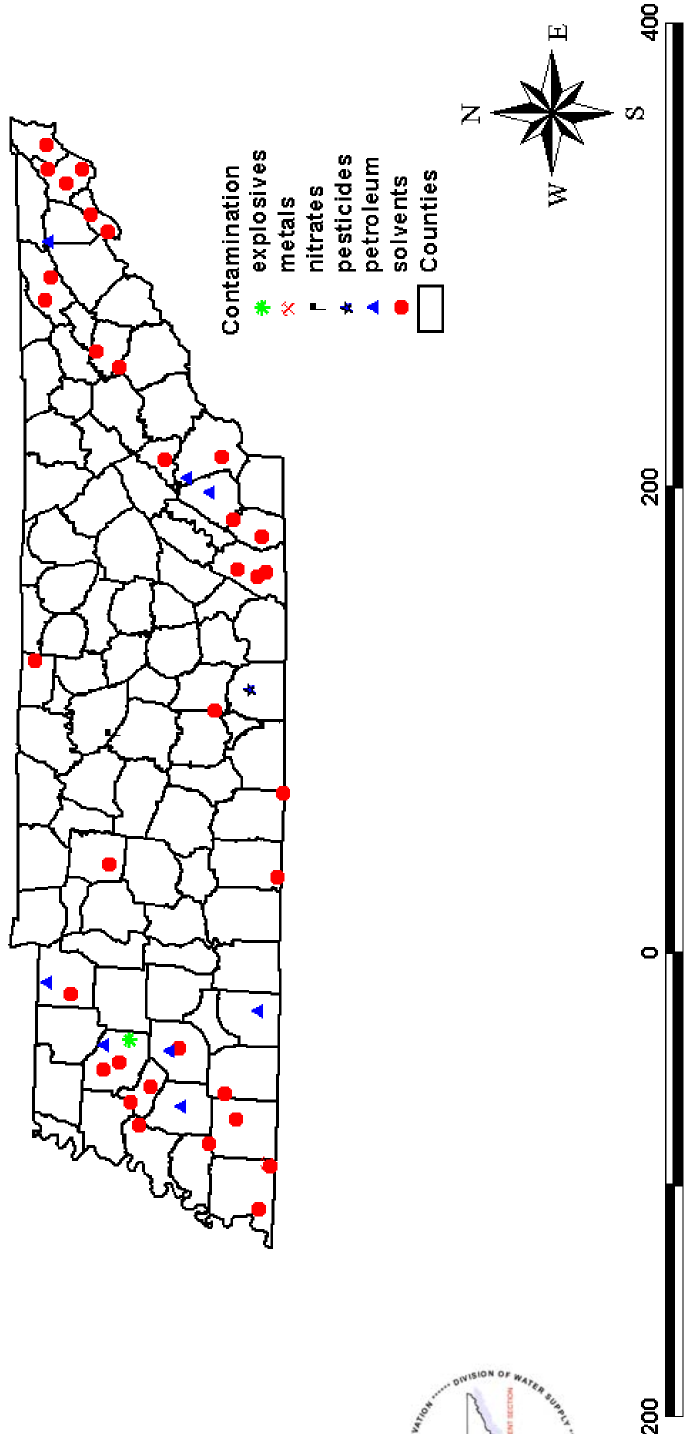


Figure 5

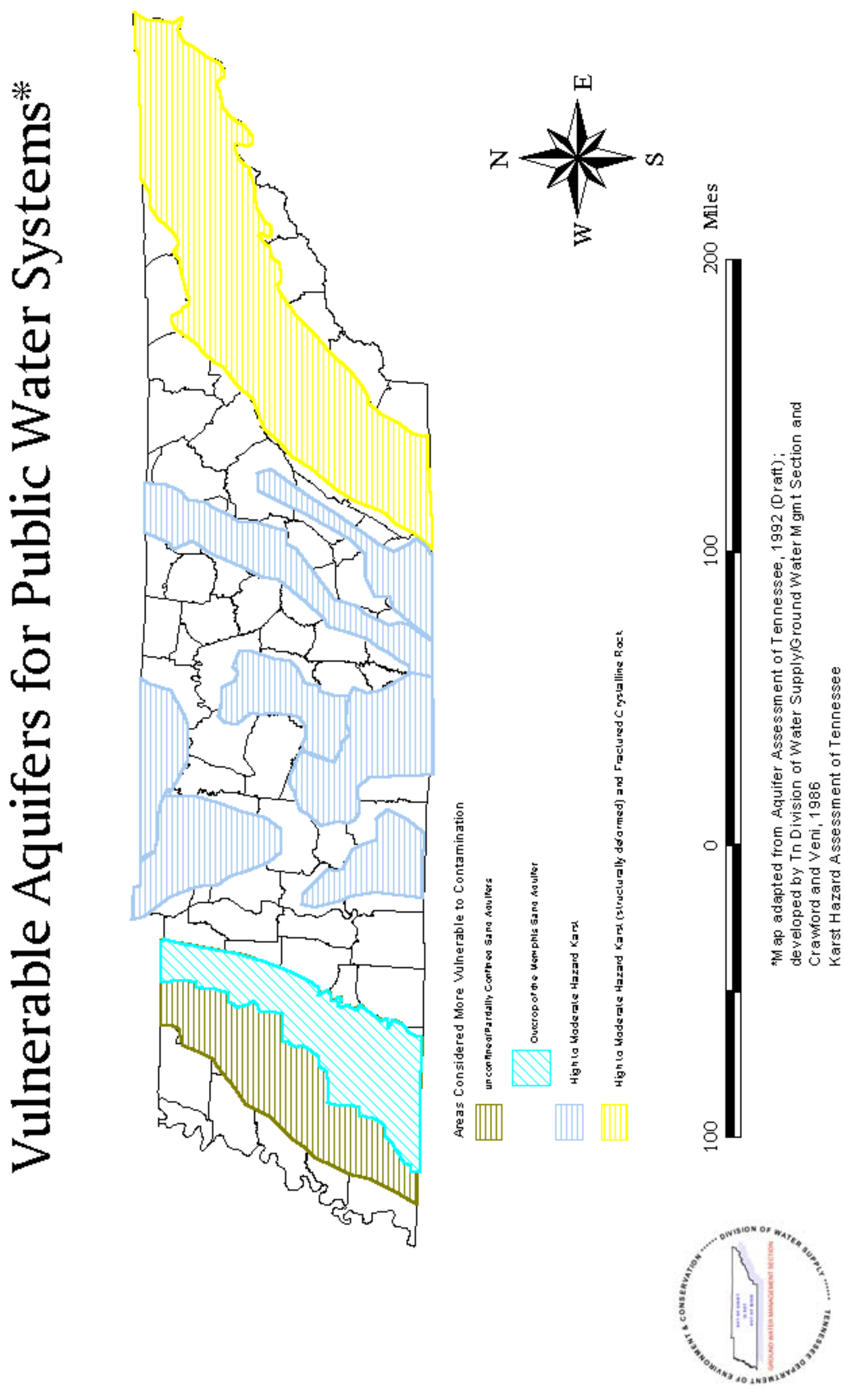

Vulnerable Aquifers for Public Water Systems*
Areas Considered More Vulnerable to Contamination
Unconfined/Partially Confined Sand Aquifers
Outcrop of the Memphis Sand Aquifer
High to Moderate Hazard Karst
High to Moderate Hazard Karst (structurally deformed) and Fractured Crystalline Rock
N
E
S
W
100
0
100
200 Miles
*Map adapted from Aquifer Assessment of Tennessee, 1992 (Draft);
developed by Tn Division of Water Supply/Ground Water Mgmt Section and
Crawford and Veni, 1986
Karst Hazard Assessment of Tennessee
DIVISION OF WATER SUPPLY
TENNESSEE DEPARTMENT OF ENVIRONMENT & CONSERVATION

Figure 6

Tennessee's Private Water Supplies

The testing of water quality for public water systems is the responsibility of that system and this cost is passed on to the consumer as a part of the monthly water bill. Testing of private supplies are the responsibilities of the homeowners. There is no systematic monitoring of private wells and springs in Tennessee.

Private water supplies are quite vulnerable in Tennessee. The factors involved include:

1) They are generally in shallow unconfined sand aquifers or karst (wells less than 200 feet in depth and those in karst are generally open borehole once bedrock has been reached).

2) They have septic tanks in near proximity.

3) They frequently have questionable well construction.

4) They have no systematic monitoring.

The most common contamination for private water supplies is bacteriological in the form of fecal coliform from failing septic tanks. There are numerous cases of a family's well being contaminated by their own failing septic tank (with or without blasting of field lines). Particularly in Middle Tennessee, there has been in the past widespread blasting in of field lines for septic tanks to allow drainage in areas with limited soil cover. This negates the whole principle of biological action in the soils for the treatment of septic waste and allows raw sewage direct access to the ground water. This was a particularly widespread practice in the karst areas of Rutherford and Wilson County in Middle Tennessee as well as in the Pennsylvanian Sandstones and Shales of the Cumberland Plateau (Figure 1).

The Department of Agriculture, Division of Plant Industries has identified several incidences of well contamination from termite pest control. In each case, improper construction/ modification of the well led to pesticide being injected directly into or adjacent to the well.

Hand dug wells are extremely vulnerable to contamination. They are essentially surface water reservoirs rather than wells drawing ground water from the aquifer. Frequently hand dug wells are not properly abandoned. These wells are commonly used to dispose of household trash, waste oil and, in some cases, raw sewage.

Springs are quite susceptible as well. The majority of springs tested in Tennessee show at least some level of bacterial contamination. Four well-known Maury County roadside springs regularly used for collecting water for drinking were recently tested by Division of Water Supply personnel. All four tested positive for fecal coliform indicative of animal or human waste contamination. The sporadic nature of water quality in karst makes springs in Tennessee generally unsafe to drink from without testing and treatment. An increase in pathogens is common after storm events. Local citizens will frequently argue that they have not gotten sick from drinking from contaminated springs. A certain amount of immunity can be built up against pathogens; however, it is inadvisable to rely on that immunity since the contamination sources are unknown and could fluctuate greatly in intensity and makeup. Viruses such as hepatitis have even been shown to survive for a period of time in impacted ground water.

Ambient Ground Water Monitoring in Tennessee

There is currently no funding or resources for systematic statewide testing for natural (ambient) ground water quality in Tennessee. The Division of Water Supply does require periodic raw water samples from selected surface and ground water systems that may have shown or have a greater potential for contamination.

There have been special projects across the state in the past. There are two studies being conducted at present. The Mississippi Arkansas Tennessee Regional Aquifer Study (MATRAS) is a multi-state project for addressing concerns in sand aquifers, specifically centered around Memphis, Tennessee. The second study is being undertaken by the University of Tennessee at Knoxville to address the transport and viability of pathogens in karst aquifer systems. Both of these studies involve extensive collection and analysis of the local groundwater quality. These studies are being funded by Tennessee Drinking Water Revolving Fund Wellhead Protection set aside monies.

Recently, due to concerns for naturally-occurring levels of radon, uranium and arsenic in drinking water supplies nationwide, one time funding was made available to sample public ground water supplies in Tennessee.

<u>Monitoring for Radioactives and Arsenic in Tennessee</u>

The Tennessee Department of Environment and Conservation's Division of Water Supply sampled ninety - two public and private ground water supplies across the state in 2001 for uranium, radon, arsenic as well as a host of other metals to provide data to address this issue. The results have been used to assist the Division of Water Supply in determining sampling waivers and problem areas where more treatment may be required.

Radon is an inert radioactive gas produced by the decay of uranium found in many soils and geologic formations. It is dissolved in ground water if it is present and released to the atmosphere from the ground. It is trapped under and in buildings. Radon poses the greatest risk to humans by being trapped in indoor air. The EPA recommends that radon levels in indoor air should be kept below 4 pCi/L. The average outdoor concentration of radon is below 0.4 pCi/L. The EPA indicates about fifty percent of public water systems exceed the proposed MCL (300 pCi/L). Preliminary studies in Tennessee indicate that several small ground water systems in middle and eastern Tennessee will not comply with the 300 pCi/L MCL without additional treatment (Figure 7).

Until the Division of Water Supply's sampling in 2001, there was very little data for uranium in ground water in Tennessee. The standard is being lowered to 30 ppb for the maximum contaminant level (MCL) and this data was crucial for making informed decisions. The results indicate that Tennessee should have very little concern with uranium levels in ground water (Figure 8).

There has also been a question of what impact the change of the arsenic standard to 10 ppb might have. These results indicate the arsenic standard change should have little impact on Tennessee ground water systems, with none of the sample results above the proposed standard (Figure 9).

There was some testing for radon in public water systems across the state in 1999, which indicated that the radon in some water systems was well above the 300 pCi/liter standard. Further radon testing was needed in that some of those systems were not in the expected geologic setting for high radon levels. The 1999 testing also appeared to indicate that lower flow volume wells and springs tend to have higher levels of radon, possibly due to there being less "flushing" of the relatively volatile radon gas. This trend of smaller systems having the higher radon readings is consistently holding true in the 2001 sampling as well.

Only four of the 92 samples had detectable quantities of uranium with the highest being 0.5 ppb (the proposed standard is 30 parts per billion). The oddity happened to be that it was in McEwen, Tennessee on the Highland Rim in Humphreys County. There does not appear to be any correlation with high radon readings and detectable uranium within the sample (McEwen had radon at 280.8 pCi/l) or gross alpha and beta readings. It is not unexpected that there are high radon readings without corresponding uranium results in that the wells are typically going to be finished above the shales. Wells are typically not drilled into the shales that contain uranium for a ground water source because they have water quality problems from high metal and sulfur content. Radon as a gas will enter the wells drilled into the carbonate rocks overlying the shales.

Forty - nine samples were tested for arsenic. None of the samples collected had arsenic results above the proposed standard of 10 ppb. Only six samples had detectable arsenic (four with 1 ppb and two with 2 ppb).

Of the 92 wells and springs sampled, 34 were above the 300 pCi/liter standard and six were above 1000 pCi/l. With the exception of West Tennessee (where no radon was expected) and the Cumberland Plateau, the sample choices were intentionally made that would likely have high radon readings. Of the 92 samples, 33 of the wells/springs have been determined to be under the direct influence of surface water. Of those 33, 13 yielded radon results of 300 pCi/l or higher.

All of the 2001 sampling was done July through September 2001. The high radon readings were typically from water systems with less than 200,000 gallons per day average daily production. If resources were to permit further research, pumping results for one to two weeks prior the sampling event (particularly if it could be done per well) would allow a more focused approach for better statistical calculations. For community water systems, this information is still available in that the systems are required to keep monthly operating reports. Aquifer pump tests to determine aquifer yield would also be useful.

The most consistently high readings were for small community/noncommunity systems in the Highland Rim area of Middle Tennessee, although the highest reading were in East Tennessee. The majority of the high values for radon are from small community (subdivisions, trailer parks) or noncommunity (campgrounds) systems.

The Highland Rim wells/springs either side of Nashville have high readings as would be expected for Mississippian carbonates above the Chattanooga Shale (see figure below). The Chattanooga Shale is the expected source of the radioactivity in that it has low levels of uranium found in it in much of the areas where it occurs. Similarly in the Valley and Ridge (Cambrian Ordovician Carbonates) and Unaka Mountains (Crystalline Rock) of East Tennessee there are shales that are expected to be low sources of low level radioactivity. The highest radon results (3103 pCi/liter) were from a subdivision in Polk County Tennessee in the southeastern corner of the state. The second highest (2010 pCi/l) was from another subdivision in Sevier County.

It is in some ways fortunate that radon is the issue in Tennessee and not arsenic and uranium as with several other states including some in the Southeast. Radon can be removed from water relatively easily in that it is a volatile gas. Treatment for uranium and arsenic is much more complex.

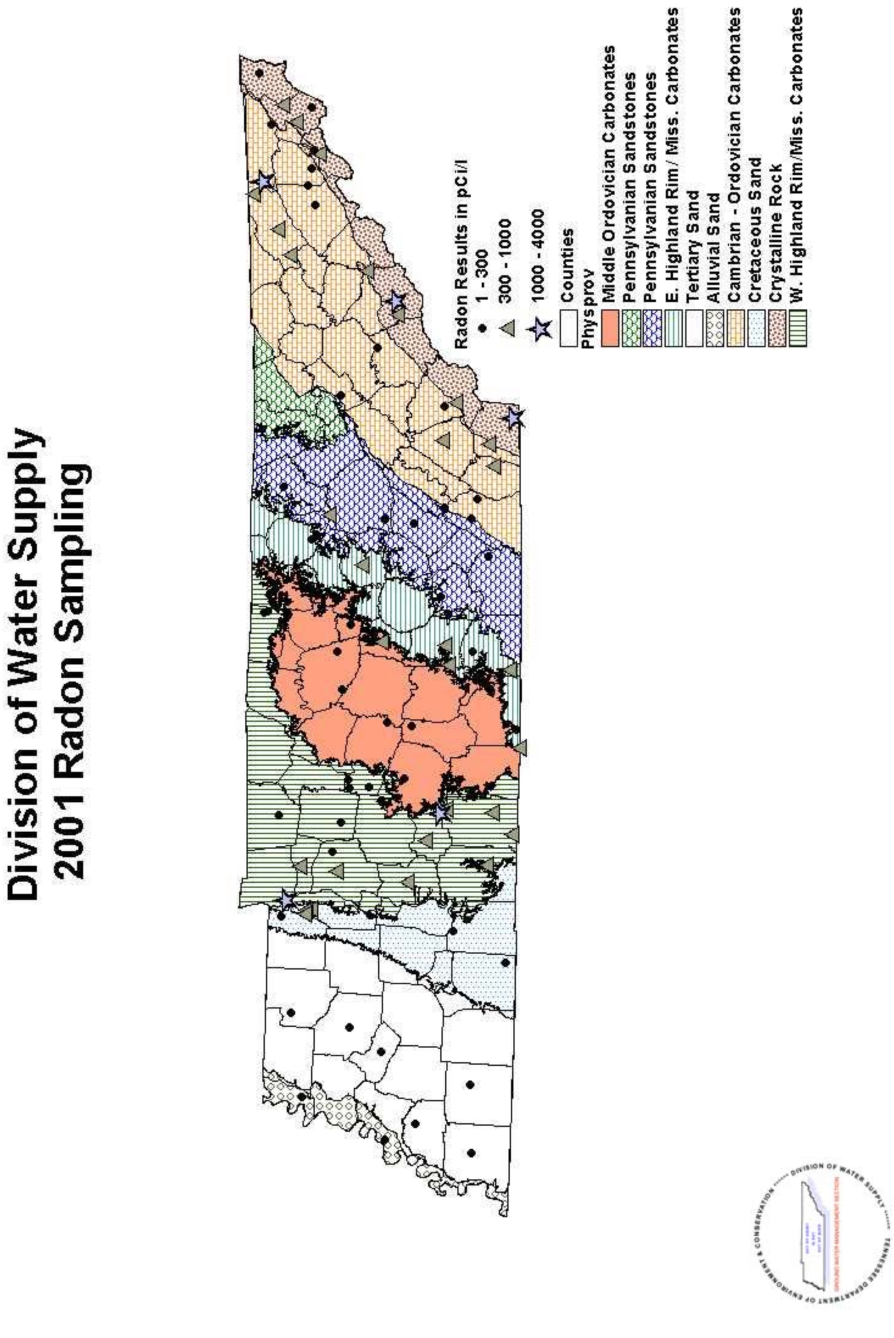

Division of Water Supply
2001 Radon Sampling
Radon Results in pCi/l
1 - 300
300 - 1000
1000 - 4000
Counties
Physprov
Middle Ordovician Carbonates
Pennsylvanian Sandstones
Pennsylvanian Sandstones
E. Highland Rim/ Miss. Carbonates
Tertiary Sand
Alluvial Sand
Cambrian - Ordovician Carbonates
Cretaceous Sand
Crystalline Rock
W. Highland Rim/Miss. Carbonates

Figure 7

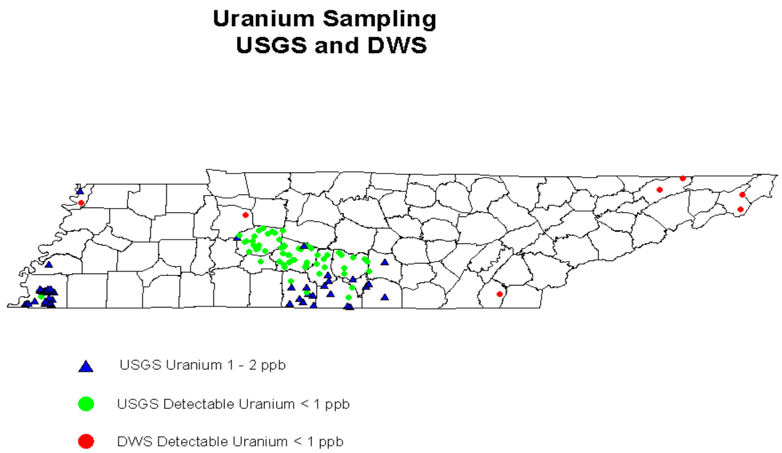


Figure 8

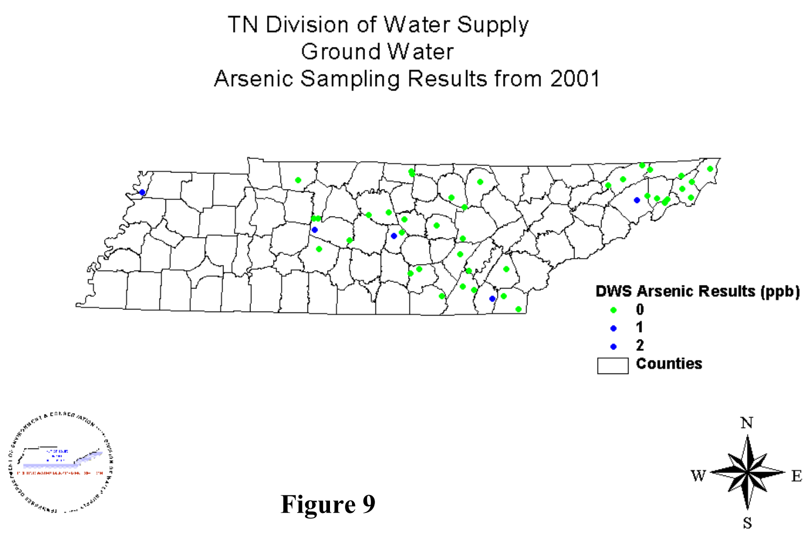


Figure 9

Water Quantity Issues

There are increasing concerns in Tennessee over sufficient levels of drinking quality water available in various parts of the state. Within the past two years there have been several public water systems that have had difficulty in keeping up with demand. There have been more instances where ground water systems are having problems than surface water systems. Extended drought conditions can critically affect aquifer recharge. This is particularly noticeable in karst areas where the aquifers rely on rapid annual recharge.

It is critical for systems to consider growth in the siting and testing of their wells. Wells sited in too close a proximity to one another have been shown to be competing against one another during pump tests. There is also a growing concern over the decreasing aquifer recharge that results from the increase of impervious surfaces from roadways, parking lots and buildings as a part of urbanization. A map indicating those public water supplies that have experienced drought problems is given as Figure 10.

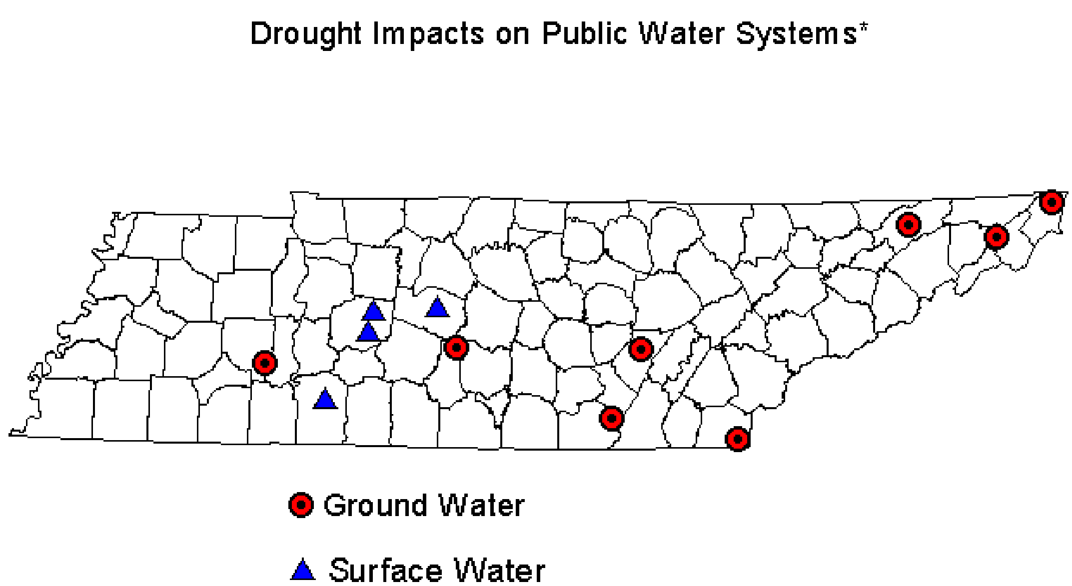


Figure 10

*Reduced Water Quality and/or Quantity

In 2000, the Commissioner of Environment and Conservation established a water supply panel consisting of business, federal, state and local government, environmental groups and other interested parties to address various water supply concerns across the state. This Panel was supported by the Environmental Policy Group which operates within the Bureau of Environment at the Department of Environment and Conservation.

One of the outcomes of the Panel's review was the identification of water supply needs in counties across the state (Figure 11). The Panel's recommendations led to the passage of the Tennessee Water Resources Information Act which registers the withdrawal of waters of the state above 10,000 gallons per day (agricultural activities were exempted). Panel recommendations also led to changes to the Water Well Act to include the licensing of monitoring well drillers and geothermal heat pump drillers and the registration of geothermal heat pump wells (although not monitoring wells).

An issue of increasing concern in Tennessee regarding water quantity is the rapidly growing trend of natural gas fired peaking and combined cycle power plants being built in Tennessee. The combined cycle plants can consume a large volume of water (up to 5-8 million gallons per day). The water is used both for cooling as well as for steam generation to run turbines. To put this into perspective, the city of Jackson with a daytime population approaching 100,000 people uses 10 to 15 million gallons per day of potable groundwater per day.

There has been particular interest in West Tennessee owing to the proximity of gas pipelines, TVA powerlines and high quality ground water (Figure 12). Good information on the quantity of water is not available, particularly for groundwater. Careful siting of power plants is essential to ensure adequate water supplies for current and future public, private and agricultural uses. The Tennessee Division of Water Supply is funding a U. S. Geological Survey study in the vicinity of Brownsville in Haywood County, Tennessee to provide a better understanding of the issue. The Brownsville study is a part of the continuation of the Mississippi Arkansas Tennessee Regional Aquifer Study (MATRAS) discussed later in this report.

Concern over the siting of power plants has been great enough that Governor Don Sundquist placed a moratorium on the permitting of additional power plants in 2001. In 2002, the Water Resources Information Act was passed. This Act requires the registration of all water withdrawal users (ground or surface water) using more than 10,000 gallons per day (with an exemption on withdrawal for agricultural purposes).

Due to the concern over massive water withdrawals near public ground water systems, there has been an amendment to the Tennessee Safe Drinking Water Act; TCA 68-221-711(8):

> "The heavy pumping or other heavy withdrawal of water from a public water system <u>or its water supply source</u> in a manner that would interfere with existing customers' normal and reasonable needs or threaten existing customers' health and safety."
> {2002 modification to the Act is underlined}

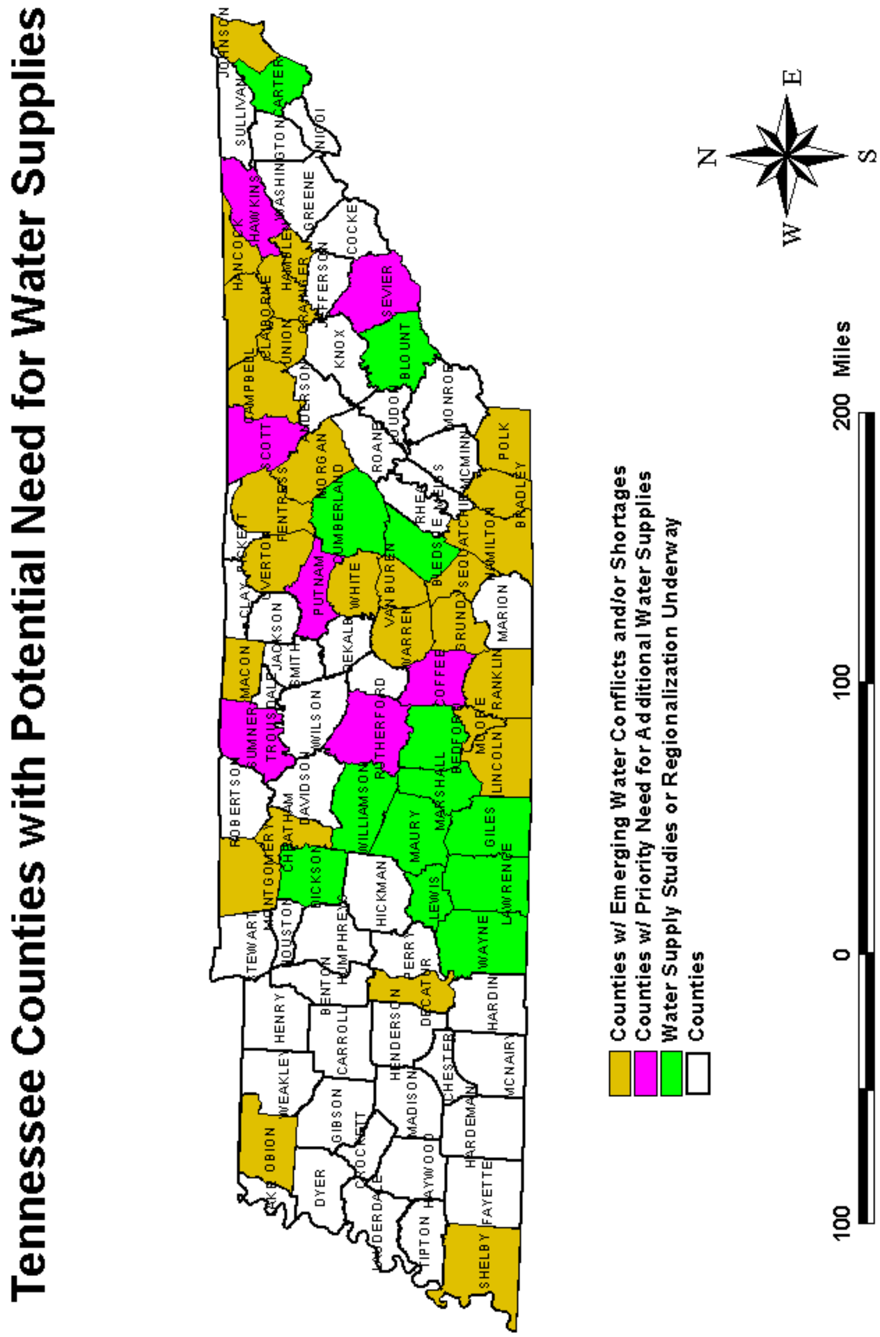

Tennessee Counties with Potential Need for Water Supplies
Counties w/ Emerging Water Conflicts and/or Shortages
Counties w/ Priority Need for Additional Water Supplies
Water Supply Studies or Regionalization Underway
Counties
100
0
100
200 Miles
N
E
S
W

Figure 11

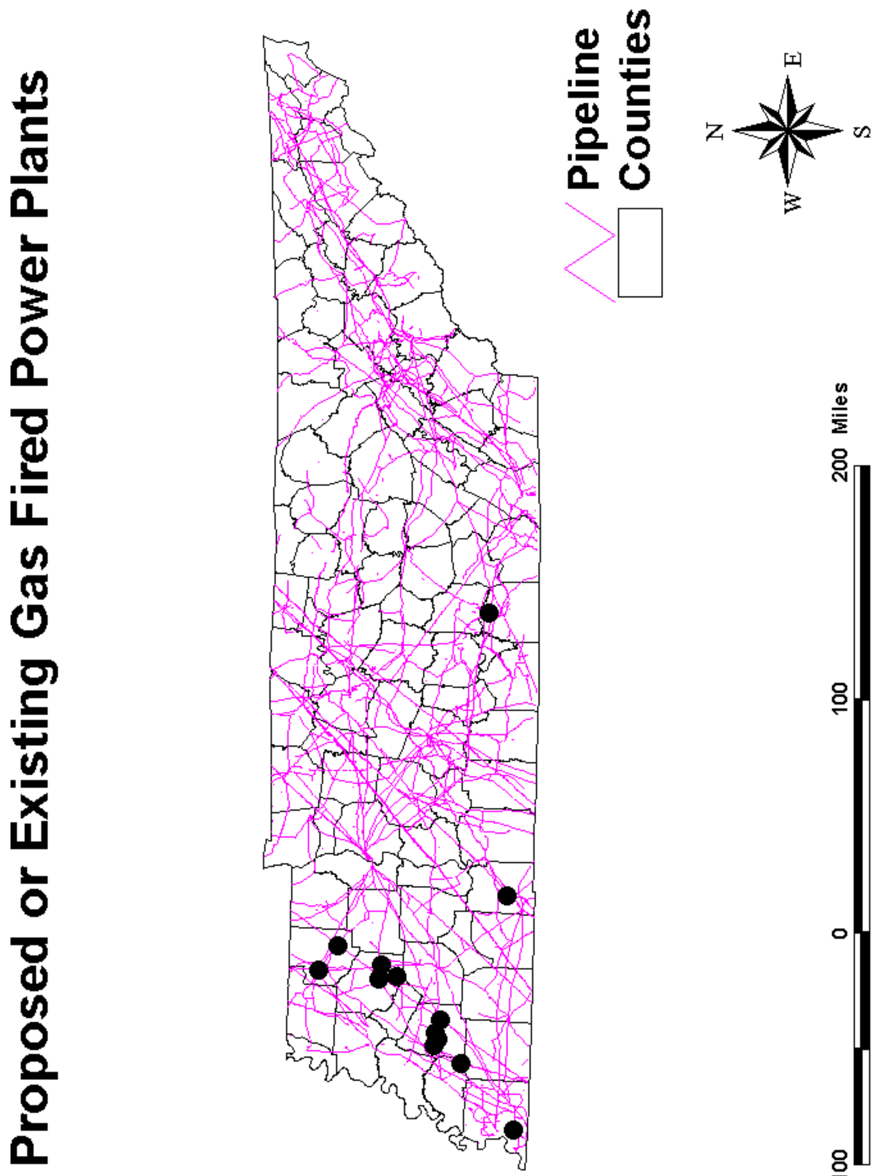

Proposed or Existing Gas Fired Power Plants
Pipeline
Counties
N
E
S
W
100
0
100
200 Miles

Figure 12

Tennessee's Ground Water Protection Program Status

Three significant changes took place in the 2002 legislative session, which will have a positive effect on ground water protection:

1) The passage of the Tennessee Water Resources Information Act of 2002, the highlights of which are:
   a. Became law on May 29, 2002.
   b. Places regulations for collection of water withdrawal information under the Water Quality Control Board.
   c. Covers the withdrawal of 10,000 gallons per day or more on any one day from any surface or ground water source.
   d. Exempts agricultural, including nursery, withdrawals from having to be registered and reported to state.
   e. Requires at least an annual report of water withdrawal to the state.
   f. Attaches no fees to the withdrawal of water.
   g. Allows a penalty of $50 to $7,500 to be assessed for failure to register or report the withdrawal of water.
   h. Gives the Commissioner of the Department of Environment and Conservation the power to collect and compile water quantity data, make investigations, conduct inspections, and collect samples with regard to water quantity and promulgate rules.
   i. Instructs the Commissioner to appoint a technical advisory committee to advise the Commissioner on the state's water resources and future planning efforts.

2) Revisions to the Water Well Act, the salient points of which are:
   a. Became law on May 29, 2002.
   b. Requires persons drilling geothermal and monitoring wells to be licensed.
   c. Does not have a provision to allow for the grandfathering of a license to individuals currently drilling geothermal or monitoring wells. Everyone desiring to drill geothermal or monitoring wells must apply for and pass a written examination
   d. Changes water well to well so that it includes monitoring and geothermal wells.
   e. Includes several new or revised definitions such as well, geothermal well, monitoring well, and well owner.
   f. Makes it unlawful for any well to be drilled or closed except by a licensed individual.
   g. Separate fees for each license so that every license has a fee associated with it. A person holding a water well, geothermal well, monitoring well, pump installer, and equipment installer license would have to pay $400 to renew all 5 licenses.

h. Expands the rig operator coverage to pump and equipment installers meaning a person working under the supervision of a licensed equipment or pump installer license could be so designated by the licensee as an operator under his/her license.

i. Removes the electrical provisions from the Act so the department will no longer have to inspect the wiring to the house.

j. The property owner can no longer dig a well for his own use unless properly licensed.

k. A license may be revoked if licensee fails to comply with an order or has been convicted of a felony.

l. No geothermal or water well may be drilled with the owner or driller first filling a notice of intent with the department. Regulations will be developed on the manner of the notice of intent but may include email, telephone or written notice.

m. Allows any municipality or county which has adopted home rules to operate well construction program in their area. License program will remain with the department. The certificate allowing a municipality or county to have this authority is valid for 5 years.

3) The amendments to the Tennessee Safe Drinking Water Act which address source water protection and quantity:

(5) The discharge by any person of sewage <u>or any other waste or contaminant</u> at such a proximity to the intake<u>, well or spring</u> serving a public water system in such a manner or quantity that it will or will likely endanger the health or safety of customers of the system or cause damage to the system.

(8) The heavy pumping or other heavy withdrawal of water from a public water system <u>or its water supply source</u> in a manner that would interfere with existing customers' normal and reasonable needs or threaten existing customers' health and safety.

{T.C.A. 68-221-711 (5) & (8); 2002 changes underlined for emphasis}

The following table (Table 2) is a summary of the status of Tennessee's ground water protection programs:

TABLE 2
Summary of Tennessee's State Ground Water Protection Programs

Programs or Activities	Implementation Status	Responsible State Agency
Active SARA Title III Program	unknown	Tennessee Emergency Management Agency
Ambient ground water monitoring system	None	
Aquifer vulnerability assessment	Preliminary assessment done in 1992	Tennessee Department of Environment and Conservation/ Division of Water Supply
Aquifer mapping	None	
Aquifer characterization	Limited	Tennessee Department of Environment and Conservation/ Division of Water Supply
Comprehensive data management system	Department-wide GIS is progressing; Department is developing IRIS Integrated Resource Information System)	Tennessee Department of Environment & Conservation/ Division of Information Resources
EPA-endorsed Core Comprehensive State Ground Water Protection Program (CSGWPP)	Draft was submitted in 1996. No further drafts or approval from EPA.	Tennessee Department of Environment & Conservation/ Division of Water Supply
Ground water discharge permits	Discharge permits are issued under the Underground Injection Control Program	Tennessee Department of Environment &

		Conservation/ Division of Water Supply
Ground Water Best Management Practices	unknown	Tennessee Department of Agriculture/ Division of Agricultural Resources/ Nonpoint Source Section; Tennessee Department of Community Assistance/Pollution Prevention Program
Ground Water legislation	Tennessee Water Quality Control Act includes ground water as "waters of the state"; Water Resources Information Act of 2002 requires the registration of ground water withdrawals of more than 10,000 gallons per day (agricultural activities exempt). 2002 Amendments to the Tennessee Safe Drinking Water Act included provisions for addressing contamination/potential contamination of contaminants being dumped/discharged in proximity to public water supply well and spring source areas. The amendments also include a provision to address excessive water withdrawals which may impact a public water supply. Changes in the Underground Injection Control Regulations in 2001 under the Water Quality Control Act allow for the denial of injection permits within wellhead protection areas.	Tennessee Department of Environment & Conservation/ Division of Water Supply
Ground water classification	Ground Water Classification Regulations promulgated under the Tennessee Water Quality Control Act in 1999. Classification is broken down into Special Source Ground Water; General Use Ground Water; Limited Use Ground Water; Site Specific Impaired Ground Water; and Unusable Ground Water.	Tennessee Department of Environment & Conservation/Division of Water Pollution Control

Ground water quality standards	Maximum Contaminant Levels (MCLs) used as standards as well as standards for naturally occurring ground water constituents under the Ground Water Classification Regulations	Tennessee Department of Environment & Conservation/ Division of Water Supply & Division of Water Pollution Control
Interagency coordination for ground water protection initiatives	Limited	Tennessee Department of Environment & Conservation/Division of Water Supply
Nonpoint source controls	unknown	Tennessee Department of Agriculture/ Division of Agricultural Resources/ Nonpoint Source Section
Pesticide State Management Plan	Approved	Tennessee Department of Agriculture/ Division of Plant Industries
Pollution Prevention Program	Established	Tennessee Department of Environment & Conservation/ Division of Community Assistance/Pollution Prevention Program
Resource Conservation and Recovery Act (RCRA) Primacy	Established	Tennessee Department of Environment & Conservation/Division of Solid Waste Management
State Superfund	Established	Tennessee Department of Environment &

		Conservation/ Division of Superfund
State RCRA Program incorporating more stringent requirements than RCRA primacy	Established	Tennessee Department of Environment & Conservation/Division of Solid Waste Management
State septic tank regulations	Established	Tennessee Department of Environment & Conservation/ Division of Ground Water Protection
Underground storage tank installation requirements	Established	Tennessee Department of Environment & Conservation/ Division of Underground Storage Tanks
Underground Storage Tank Remediation Fund	Established	Tennessee Department of Environment & Conservation/ Division of Underground Storage Tanks
Underground Storage Tank Permit Program	Established	Tennessee Department of Environment & Conservation/ Division of Underground Storage Tanks
Underground Injection Control Program	Regulations adopted in 1985. Primacy submittal to EPA in 2002.	Tennessee Department of Environment & Conservation/ Division of Water Supply
Vulnerability assessment for	Preliminary assessment done in 1994; aquifer vulnerability done as a part of the	Tennessee Department of

drinking water/ wellhead protection	Source Water Assessment Program submittal to EPA in 1999	Environment & Conservation/ Division of Water Supply
Well abandonment regulations	Changes to the Water Well Act in 2002 require any closure by licensed driller; no closure requirement in place	Tennessee Department of Environment & Conservation/ Division of Water Supply
Wellhead Protection Program (EPA-approved)	Wellhead Protection Regulations adopted and approved by EPA in 1994	Tennessee Department of Environment & Conservation/ Division of Water Supply
Well installation regulations	Initial well construction law was promulgated in 1967. Several updates within the past ten years..	Tennessee Department of Environment & Conservation/ Division of Water Supply

Water Supply Panel Recommendations

The Tennessee Water Supply Panel established by Commissioner Hamilton in 2000, consisted of business, federal, state and local government, environmental groups and other interested parties to address various water supply concerns across the state. This Panel was supported by the Environmental Policy Group which operates within the Bureau of Environment at the Department of Environment and Conservation. The following general ground water recommendations were made as it wrapped up in 2001:

1. Provide greater ground water control and protection; i.e., well permitting as in Shelby County (Shelby County includes monitoring wells and geothermal heat pump wells).

2. Develop a mechanism for regional planning and interstate cooperation and develop strategies to overcome barriers to them

3. Coordinate among local, state and federal government who effect water

4. Improve data collection, assessment and dissemination, including monitoring, to determine status of the resource and to develop an accurate inventory

5. Incorporate funding strategies and other incentives with any initiatives (that addresses programmatic needs and projects)

6. Develop and implement conservation strategies

7. Educate population about the resource - groundwater recharge areas, runoff and permeable surfaces in development

8. Develop a "Shelby County water resources board" planning ability to plan for the resource.

Other Ground Water Issues in Tennessee

There is no systematic ambient water quality monitoring in Tennessee. Public water systems are required to monitor their finished water but not their raw water. There is no monitoring of private wells and springs in Tennessee. Testing of private supplies is the responsibility of the homeowner. The most common contamination is bacteriological in the form of fecal coliform from failing septic tanks. Failing septic tanks are particularly common in karst areas.

Costs associated with water quality improvements are complex, and not readily available for developing a complete cost/benefit assessment. There is a major gap between threatened susceptible ground water resources and implementation of resource evaluation and pollution prevention programs. Additional resources are needed to fill the gap to better understand ground water quality and implement needed protection programs. Further resources are needed to:

- Perform ambient water quality monitoring and ground water evaluations across the state.
- Provide assistance to small community water systems to develop local ground water protection programs.
- Monitor and assess ground water contributing to ecologically vital and sensitive ground waters.
- Provide pollution prevention technical assistance to small businesses located within wellhead protection areas.
- Provide education to the public, government and industry.
- Provide assistance to local government in the development of local ground water/wellhead protection programs.

Ongoing Activities

The Tennessee Department of Environment and Conservation (TDEC), TDEC's counterparts in Mississippi and Arkansas; Memphis Light Gas and Water; the Tennessee, Mississippi and Arkansas branches of the US Geological Survey and the Ground Water Institute at the University of Memphis are undertaking an evaluation of ground-water resources in the Memphis area, Tennessee, Mississippi, and Arkansas as well as the effects of ground-water movement from recharge areas and across state lines. The evaluation currently being undertaken is being referred to as the Mississippi, Arkansas and Tennessee Regional Aquifer Study (MATRAS). The study will be underway for several years to come. The Division of Water Supply is providing funding from the Drinking Water State Revolving Fund set aside for Wellhead Protection.

The Memphis area of Shelby, Fayette, and Tipton Counties, Tennessee, Crittenden County, Arkansas, and DeSoto and Tunica Counties, Mississippi have and are experiencing increased urban growth and development. The occurrence of urban sprawl in the study area has created strains on existing infrastructure of which water resource is a major component. Another potential problem is that urban growth in eastern Shelby County may directly impact the quantity and quality of recharge to the Memphis/Sparta aquifer, the principal source of water supply in Shelby County, Tennessee and DeSoto County, Mississippi. Increased use of ground water to meet growing demand in Shelby County, DeSoto County, and Tunica County will affect movement of ground water across the State line and may affect water availability in these areas.

The objectives of MATRAS are:

1) To determine "critical" source areas of water to the Memphis/Sparta aquifer {"Critical" source areas are those areas that contribute significant amounts of ground water to pumping centers, have high susceptibility for contaminant occurrence and migration, are under stress due to increased urbanization, or result in possible interference reducing well yields and water levels between utility districts, municipalities, or across State lines};

2) To evaluate changes in ground-water production and the impact on "critical" source areas and the ground-water resource, and

3) To compile and maintain available geologic and hydrologic data from multiple agencies into a consistent database.